Battery Cabinet Hardware v1.0

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1 Scope

This specification defines the requirements for a 75KW stand-alone battery cabinet, with 48VDC nominal voltage, self powered from the AC line, used in a DC system for offline backup functions during AC outages only.

2 Contents

3 Overview

When data center design and hardware design move in concert, they can improve efficiency and reduce power consumption. To this end, the Open Compute Project is a set of technologies that reduces energy consumption and cost, increases reliability and choice in the marketplace, and simplifies operations and maintenance. One key objective is openness—the project is starting with the opening of the specifications and mechanical designs for the major components of a data center, and the efficiency results achieved at facilities using Open Compute technologies.

One component of this project is the battery cabinet. The battery cabinet is a standalone independent cabinet that provides backup power at 48VDC nominal to an Open Compute Project server triplet (custom rack, see the *Open Compute Project Server Chassis and Triplet Hardware v1.0* specification) in the event of an AC outage in the data center. The batteries are a sealed VRLA 12V nominal, high-rate discharge type with a 10 year lifespan, commonly used in UPS systems, connected in a series of four elements for each group (called a string), for a nominal string voltage of 48V DC. There are five strings in parallel in the cabinet.

The backup power requirement for the principal application is in the range of 42KW (6 x 7KW) to 72KW (6 x 12KW). The preliminary power level for all calculations is **56.6KW** (6 x 9KW + 2.6KW) for the whole cabinet.

The principal application (see Figure 1) is a system load composed of six independent main loads (9KW each nominal) and one secondary load (2.6KW nominal). The main load is the server load (offline backup power) while the secondary load is the IT switches load (online power and backup power). All loads are connected in parallel to the battery cabinet for the related backup functions. However:

- The main load is powered by the batteries only during an AC outage, while it is powered by a separate AC/DC source when AC is present.
- The secondary load (SCL) is always powered by the rectifiers and batteries, whether or not AC is present. Any controllers needed in this application may also run on batteries if they need to be functional all the time.

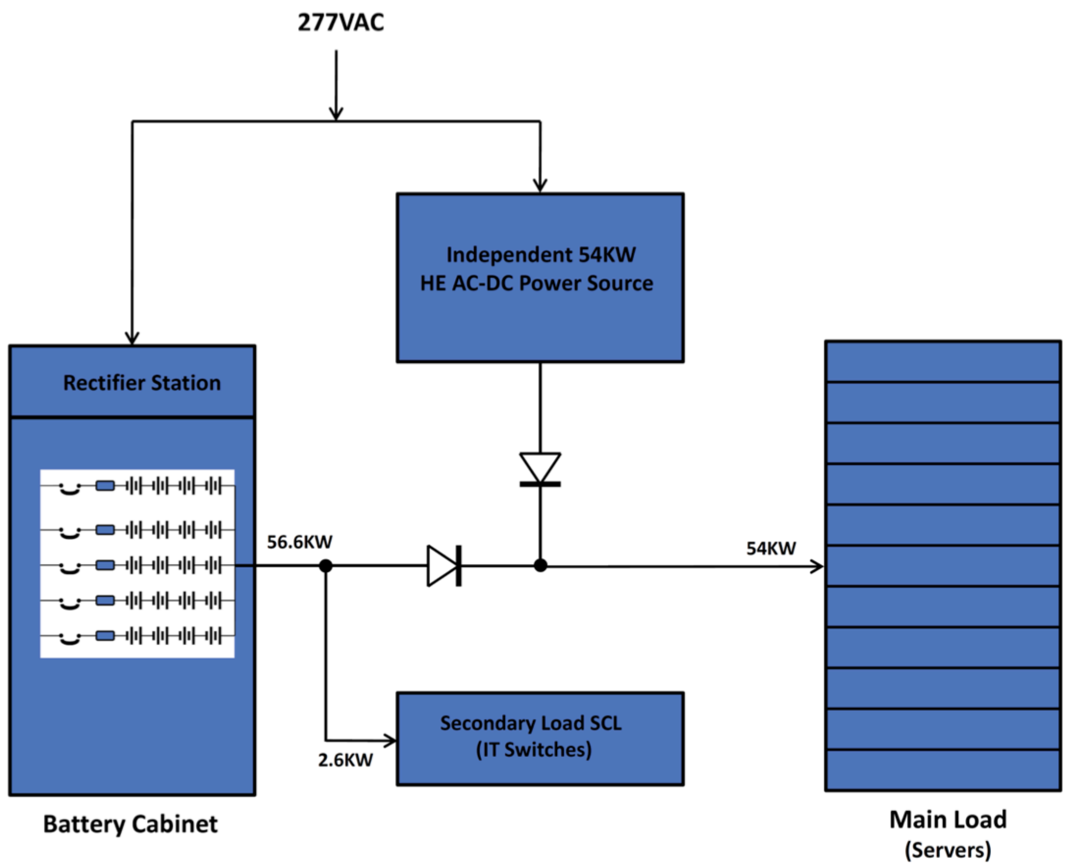


Figure 1 Simplified Block Diagram of the Principal Application

There are three rectifiers in the cabinet fed directly by 277VAC (phase and neutral from the 480VAC three-phase power distribution) implementing the functions of charger, trickle charge, and supply for the SCL. During the trickle-charge phase, the rectifier station supplies just enough current to compensate for the battery's internal leakage plus feeding the SCL that is always present (2.6KW maximum).

The rectifiers work in conjunction with their controller (which may or may not be included within the rectifiers' shelf itself) for the charging process and control.

The same controller may also handle the real-time impedance battery monitoring process, in addition to the charging process and control. Otherwise, a second "slave" controller may be used.

The controller continuously monitors the health of the batteries (reading of V, I, T, Z, or a subset, including remote data accessibility, EOL approaching status_alarm, and so forth).

The cabinet includes also several breakers, quick fuse disconnects, Hall sensors, a high current DC bus bar, and an LVD device.

The battery cabinet is used in conjunction with information technology equipment and is designed to meet the BS EN 60950-1:2006 standard specification for safety of IT equipment.

3.1 License

4 Cabinet Material and Dimensions

The size of the cabinet is 24" x 36" x 84" (width x depth x height).

The sheet metal needs to meet the robustness and all related requirements for this type of heavy-duty application, including material reliability and protection against rust. The cabinet is rated for seismic area Zone 4, is a custom design, and seamlessly integrates with the main system. The chassis' metal finishing is pre-plated material and painted. Electro-zinc-plated material is not allowed. The cabinet must have slots to receive a pallet jack for placement and setting. Walls enclose the cabinet completely, with the front panels easily detachable for serviceability. Small air slots are allowed on the front wall and on top side of the back wall for cooling purposes only. The objective is to maximize the airflow impedance between the front of the cabinet (cold aisle) and the back (hot aisle), so that airflow cannot easily go through it (see section 5). Note that batteries need to be kept at the right temperature conditions to maximize their lifetime.

5 Environmental Requirements

The operating temperature range of the battery cabinet is +5°C to +45°C (+41°F to +113°F).

Note: The ideal VRLA battery temperature for longest service life is typically +25°C (+77°F).

At system level, the temperature range of the cold aisle (the front of the cabinet where inlet air slots are) will vary from +5°C (+41°F) to maximum +30°C (+86°F), as a typical cold aisle temperature is not predictable. The maximum temperature of the hot aisle (back of the cabinet where outlet air slots are) is +45°C (+113°F).

There is an air pressure gradient between the front of the cabinet and the back causing air suction through it (which is proportional to the openings present on the front and back walls), and able to provide some cool air to the batteries. However, as previously mentioned (in section 4), airflow through the cabinet must be minimized as much as possible.

- Storage temperature range is -40°C to +70°C (-40°F to +158°F).
- Transportation temperature range is -55°C to +85°C (-67°F to +185°F).
- Operating and storage relative humidity is 10% to 90% (non-condensing).

The ODM is responsible for testing to prove this requirement as well as to propose a shock and vibration qualification test procedure under operative, stationary (storage), and transportation conditions.

6 Backup Capabilities, Topology

The battery cabinet provides 45 seconds of runtime at full load. *Runtime* is defined as a discharge of the whole battery pack (with five battery strings) from the fully charged voltage of 54V (13.5V x 4), to a minimum of 42V (10.5V x 4).

Lower levels of the minimum allowed voltage may vary with the battery selection (42V is equivalent to a minimum cell voltage of 1.75V; there are six cells in one battery). The load is a constant power load type; the battery type will be selected based on these requirements. Each string is composed of four 12V, UPS-grade, high-current discharge, sealed lead-acid batteries connected in series. The nominal output voltage of one string is 48VDC, while the floating voltage at trickle charge is 54V (full charge status).

Note: While the actual floating voltage value can differ depending on battery type, in this specification, 54V is considered as the fully charged level (trickle charge voltage), and 42V as LVD threshold (Low Voltage Disconnect).

Each battery string sits on one of five levels in the cabinet, where they are placed in parallel to the DC output bus bar to achieve the required backup power.

The IEEE defines end of useful life (EOL) as the point when the battery can no longer supply 80% of its rated capacity in ampere-hours. Because the relationship between ampere-hours after aging and quick discharge time is not linear, a 20% reduction in capacity (EOL battery) generally results in a much bigger reduction of quick discharge time. For example, a battery string that easily supports 60 seconds of fast discharge time at full load when new, will only support about 40 seconds or less when it reaches its end of useful life status (at the same load conditions).

Important: The minimum required backup time of 45 seconds, at worst conditions with EOL batteries, needs to be guaranteed and experimentally qualified.

7 DC Bus Bar, Components

The cabinet includes a bus bar where all the battery strings are connected in parallel. The bus bar is designed to make the interconnection with the main load racks simple and direct, with power cables routed in a clean layout.

There are no fuses in series to the main (+) and main (-) bus bar outputs, while each battery string includes its own protection fuse with a quick disconnect, which is also used for servicing purposes (it must be a DC high-current part).

The battery cabinet is used as short-term backup for the main load and SCL during an AC outage, but it also continuously powers the SCL (composed of two independent banks of 1.3KW each for a total power of 2.6KW, see sections 3 and 10).

There are several DC circuit breakers sourcing power from the bus bar:

- Six DC breakers rated 250A each (minimum) power the main load during an AC outage (6 X 9KW).
- Two DC breakers rated 50A each (minimum) are used to permanently power the SCL (2 x 1.3KW).

The breakers must be delayed-type components to guarantee improved pulse tolerance helping to minimize nuisance tripping.

8 Configurability, Scalability

The cabinet is sized to support 56.6KW of nominal backup power (main load + SCL). However the design is flexible enough to easily configure cabinets with lower (or higher) power rating, depending on the configuration of the system used in the various applications, and functions.

Lower power levels can be achieved in two ways:

- By installing less than five battery strings or lower capacity batteries. In this configuration the over current threshold of the charger (rectifier station) needs to be lowered accordingly so as to not exceed the C/5 recharge current. Circuit breakers with updated ratings can be replaced accordingly.
- By instituting a (4+1) redundancy scheme. One battery string is used only in the event of battery failure elsewhere in the cabinet.

Higher power levels can be achieved by replacing the batteries with a model with a higher rating, provided it fits into the cabinet. In this case the recharge current rate may be lower than C/5 since the rectifier station remains the same, unless it is also upgraded accordingly.

Important: The cabinet chassis accepts the installation of several battery form factors without the need to change chassis part numbers for different battery sizes. The seismic Zone 4 requirement is met in the worst configurations, with the highest total battery cabinet weight.

8.1 Cabinet Overall Power Sizing

The wiring, bus bar, LVD, and so forth need to be electrically sized for a maximum backup capability of **75KW** (maximum configurable power) in order to be able to scale up the power if needed. However power would be delivered **only** during short-term backup in the event of an AC outage. Therefore, the copper must be sized accordingly without necessarily considering 75KW as online power for the corresponding design.

9 DC Inrush Current

The main load includes a total capacitance that could exceed 0.1 Farad. Fuses should not blow and breakers should not trip when the battery cabinet is first connected to the main system on activation of the breakers. In fact, each of the six breakers could see a capacitance of approximately 20,000 milli-Farad at the first DC turn ON, if DC inrush control at the system level is not included.

10 Battery Charger, Performances, Load Power

The cabinet includes a shelf with 3 rectifiers in parallel, called a rectifier station, which may include a rectifier controller within. The nominal power is sized to drive the batteries at a maximum charging rate of C/5, and to source continuous power to the SCL.

Important: The controllers for the Low Voltage Disconnect, battery, and rectifiers are mentioned throughout the specification as if they were independent devices, but they may be one device only.

The input voltage of the station is 277VAC RMS (see section 11.1), and it has one rectifier connected to each of the three 277VAC phase-to-neutral available feeds in the 480VAC three-phase power distribution scheme. A three-phase NEMA connector powers the station. The SCL (IT switches) is powered by 48VDC nominal. The maximum power consumption for the IT switches used for each server triplet is **1.3KW**, corresponding to 31A at the 42V LVD threshold (see section 12); the circuit breaker for each chassis load is sized at 50A DC minimum (see section 7).

The total DC power necessary for both chassis (the SCL) is **2.6KW** (2 x 1.3KW).

- During the quick discharge phase (backup), the cabinet must be able to deliver **56.6KW** of power (54KW + 2.6KW), with the battery strings' voltage decreasing from 54V floating level (2.25V per cell) to 42V LVD level (1.75V per cell).
  A power level of 9KW at 42V corresponds to 214A, so the circuit breakers used for each of the six main loads should be sized at 250A DC min (see section 7). The total maximum power of 75KW corresponds to 1785A at 42VDC (maximum bus bar current).
- At the 42V level, the LVD disconnects the battery cabinet from any loads (see section 12).
- For the presence of the SCL during the charging phase the station needs to feed an additional 2.6KW of power. A battery discharged during an AC outage does not absorb all of the current delivered by the charger (station) when the main AC power is restored; the minimum voltage the battery reaches during discharge on AC failure acts as a floor when the AC power is restored. The battery voltage cannot drop further when charging resumes; rather, it rises immediately with the SCL drawing whatever current it requires (62A maximum, 2.6KW/42V), and with the batteries getting the rest.
- Under no circumstances can the battery strings' voltage fall below 42V, whether during discharge, charge, or transition phases, for example, unless the LVD threshold is reached. But in this case, the system would latch itself OFF (see also section 12) until AC power is available to the main load again.
- 48VDC output voltage must be free of disturbance or spikes during transitions of the AC mains.

11 System Sizing

The resultant battery has higher than 70AH of capacity and is a VRLA type with high-current discharge typical for a UPS application, with low impedance. The exact size of the battery and number of strings in parallel for the required power depends on the total main load, and it needs to be calculated following IEEE 485 *Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications*.

11.1 Rectifier Station (Recharge)

Based on the power needs and the maximum charging rate of C/5, the minimum power needed is at least 6KW total for all three rectifier modules (three modules must be used to balance the three-phase load). These modules are single-phase, single-range AC input (180VAC – 290VAC, 300VAC maximum) and are PF- (Power Factor) and THD- (Total Harmonic Distortion) compliant up to 290VAC RMS. The power quality requirements of one rectifier module at full load and 277VAC RMS are as follows:

- PF > 0.99
- THD < 5%

Note: At 300VAC, the modules are not expected to meet the PF and THD requirements.

The efficiency of the modules must exceed the Climate Savers Computing Initiative "PLATINUM" rating at 200VAC RMS Input. Those limits are:

- Eff > 90% at 20% load
- Eff > 94% at 50% load
- Eff > 91% at full load

The high efficiency of the rectifier helps to conserve power during the floating trickle-charge phase when the station mainly delivers power only to the SCL (2.6KW).

The rectifier station may embed the controller and is located on top of the cabinet for easy handling of AC power cabling.

12 Low Voltage Disconnect (LVD)

The cabinet includes an independent LVD device (Low Voltage Disconnect) able to isolate the batteries from any load once the string reaches 42V (1.75V per cell) of locally sensed voltage during the backup-phase discharge. The LVD will reconnect the batteries to the external load once the voltage increases above 50.4V (2.1V per cell, which must be a settable threshold) after AC mains resumes.

The LVD is required to protect the batteries against damage due to an excessive discharge. The LVD is a bi-stable device, so it doesn't waste power in any relay coil during normal operation when AC is present. The LVD must be rated 1800A minimum (see section 10). Two LVDs rated 900A each (minimum) can also be used; in this case, each LVD would power half of the main load and half of the SCL (there are two identical overall loads split in the principal application, sitting near the battery cabinet). One sole LVD is recommended, along with an embedded LVD in the bus bar, driven by the controller.

Local LVD manual override functionality as well as remote disconnect is included to manually isolate the batteries from any loads when required, and for serviceability.

12.1 Battery Voltage Plots

The figures in this section show examples of what test results performed on the battery cabinet could be, under the following conditions:

- Backup event at full load (56.6KW constant power load)
- EOL batteries

The examples show the evolution of the bus bar battery voltage after an AC outage, from t = 0 seconds.

- **Figure 2** shows a typical voltage profile of a healthy battery cabinet.
- **Figure 3** shows a failing profile. The backup time does not reach the minimum required 45 seconds, and it may also fail the Coup De Fouet condition.
- **Figure 4** shows a hard failing profile. The battery cabinet cannot withstand the load after the AC outage, resulting in a dramatic voltage drop during the first few seconds. This case is typical when one or more battery strings are failing (high internal impedance).

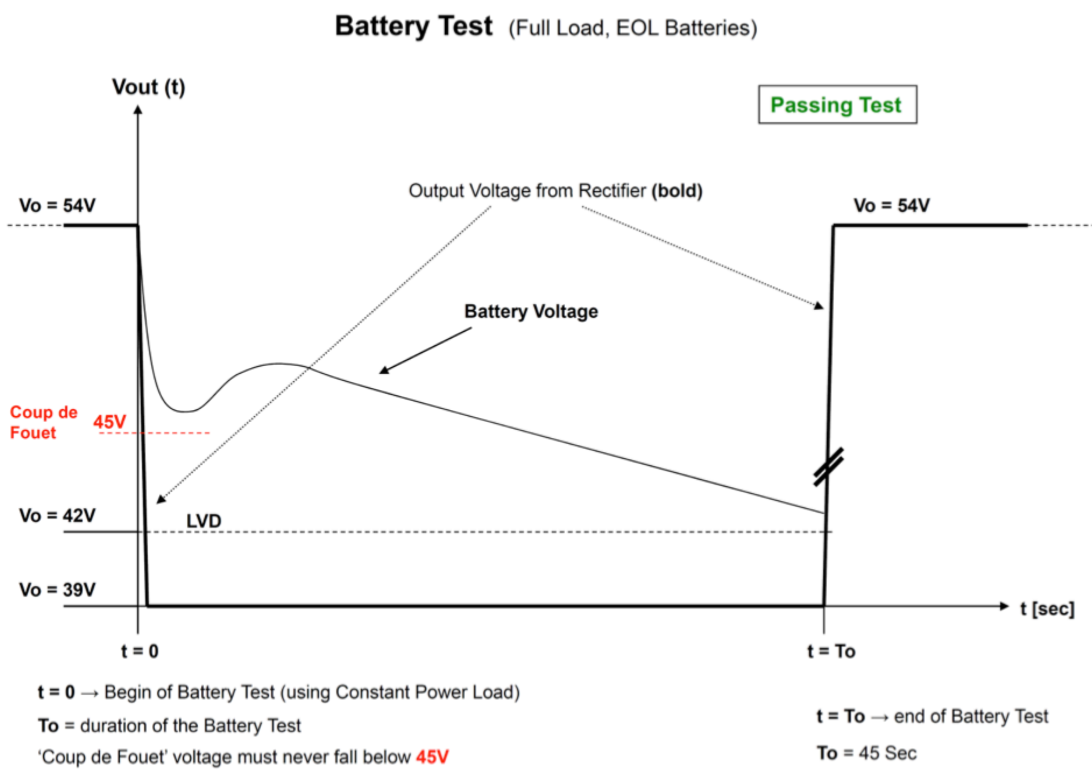


Figure 2 Passing Battery Test at Full Load (56.6KW Constant Power)

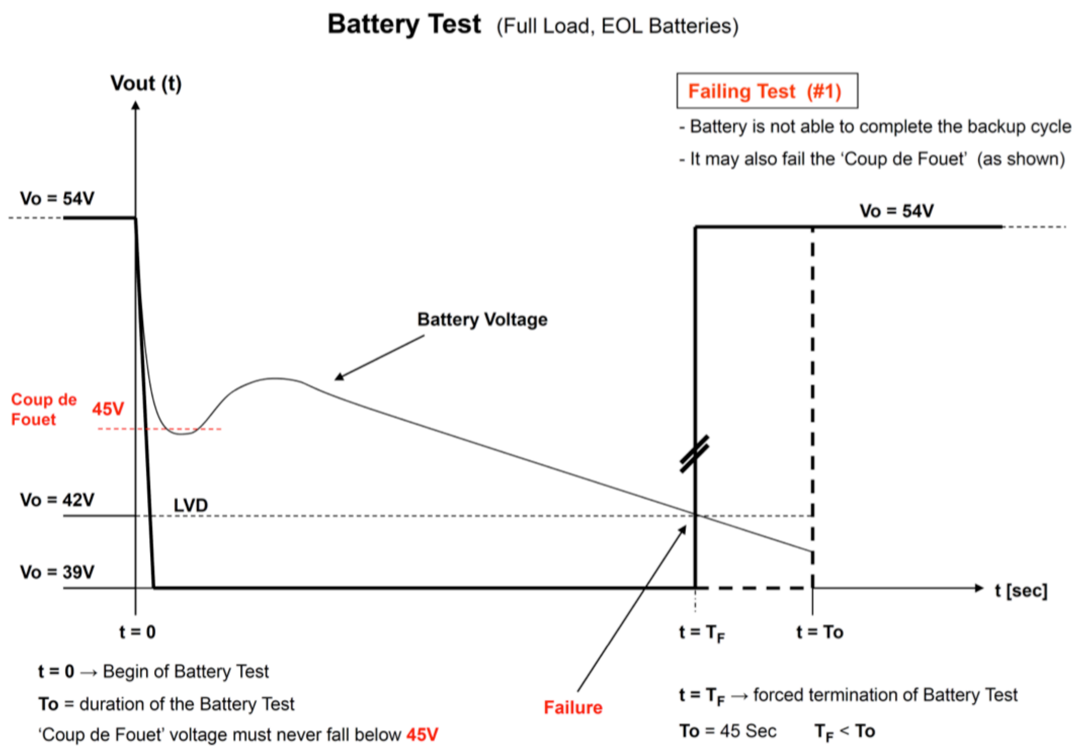


Figure 3 Failure of Battery Test at Full Load (56.6KW Constant Power)

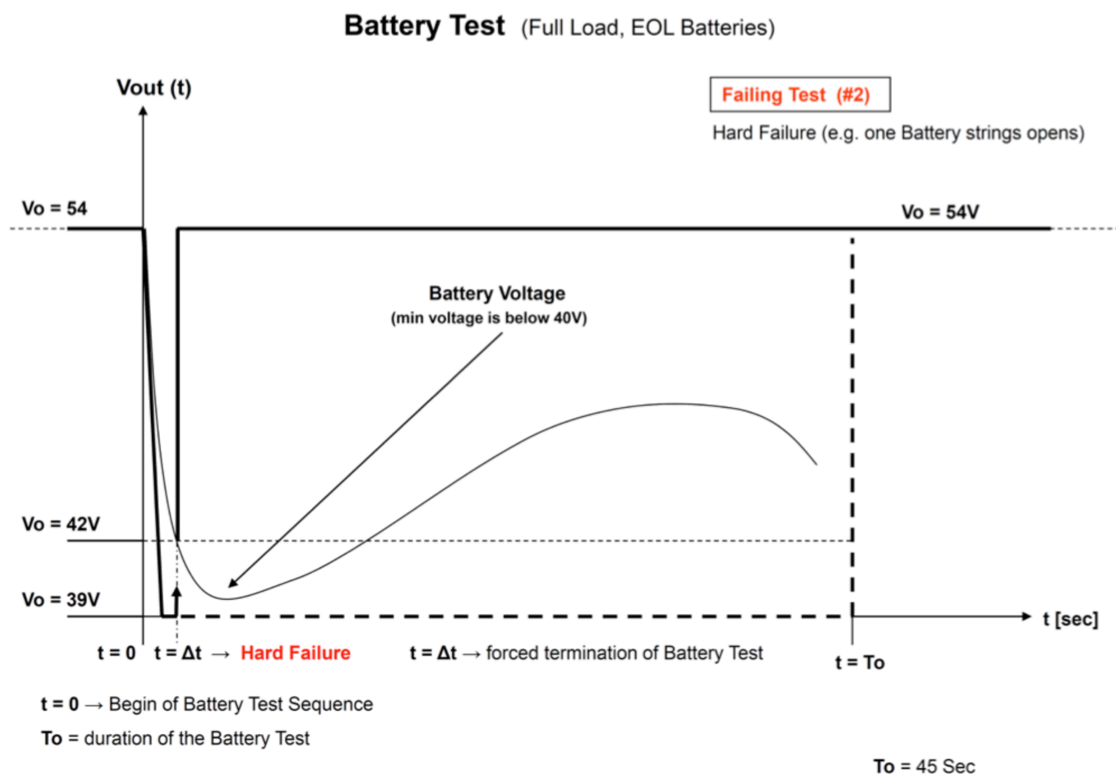


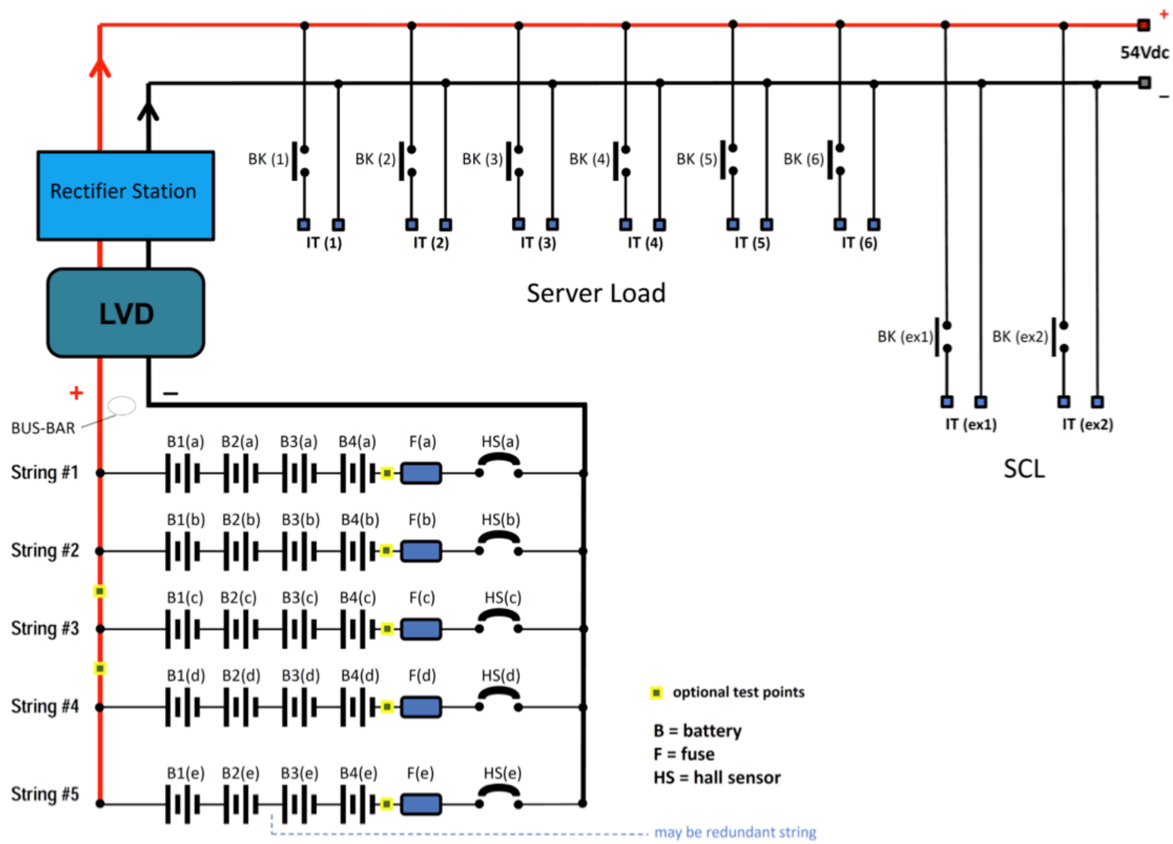
Figure 4 Hard Failure of Battery Test at Full Load (56.6KW Constant Power)

13 Battery Monitoring, Diagnostic, Service

Each individual battery includes a dedicated monitoring device that continuously checks the impedance, which gives an important indication as to the state of health of the battery. All the nodes of all devices are connected to a common local bus terminated to a controller that sits on top of the cabinet. The controller is powered by the DC battery voltage and includes an Ethernet port for network connectivity.

The monitoring devices will periodically measure the impedance of each battery and log the trend, with the controller sending an alert in advance of an approaching battery EOL status with physical location of the failing battery, and thus indicating when batteries need to be replaced. Other more conventional methodologies can be used, like ongoing battery testing or similar techniques. Life expectancy and approaching EOL status calculated through impedance measurements and history data are preferred methods because the main load (acting as a test load during the battery test) is thus never involved in any battery test procedures. Other information can be collected like voltage and temperature (battery temperature data is useful while recharging).

A monitoring protocol must be established in order to get and store real-time data for battery health (like a Web-based or Intranet repository system). Automatic alarms are sent when batteries approach their EOL status (so they can be replaced), and data collected from the monitoring system should be accessible via an industry standard protocol and interface.



Legend

Bj(i) = batteries	
F(i) = fuses	
HS(i) = hall sensors	
BK(ex1, ex2) = 50A DC breakers (for the two banks of SCL)	
BK(i) = 250A DC breakers (for the six banks of the main load)	

Figure 5 Simplified Electrical Schematic

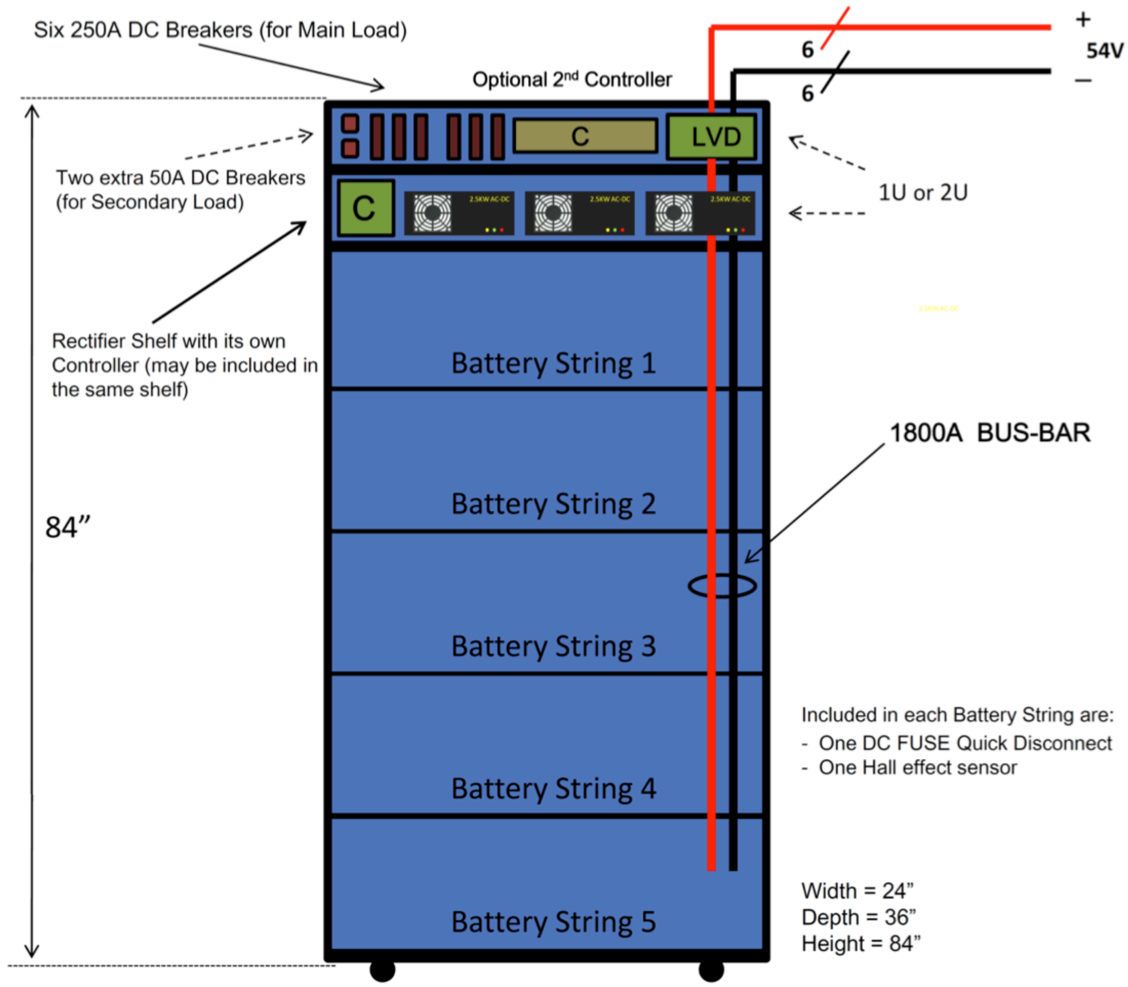


Figure 6 Sketch of the 56.6KW Battery Cabinet Assembly (Main Load Configuration)